DANGEROUS ATMOSPHERE CREATED BY STRIP MINE SPOIL

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ABSTRACT

Dangerous, low oxygen levels, commonly referred to as blackdamp, are often caused by carbon dioxide and nitrogen produced from abandoned underground coal mines. The blackdamp atmosphere from adjacent underground mine voids displaces normal air in homes through changes in air pressure. Three homes near and on a recently reclaimed strip mine are affected by blackdamp with no obvious association to deep underground mining. During periods of low barometric pressure, atmospheric levels of 12 to 25% carbon dioxide (CO_2) and near 10% oxygen (O_2) by volume entered the basements of these homes for periods exceeding 12 hours.

Drilling indicated that CO_2 was concentrated throughout the permeable mine spoil beneath one of the homes. The other two homes were adjacent to the strip mine but not undermined. The source of the CO_2 production in the strip mine was initially unknown. However, three potential sources were identified: 1) deep, open mine entries encountered during surface mining activities; 2) organic and landfill waste disposed in the mine pits; or 3) the dissolution of carbonate materials from reactive waters deep in the spoil. The source of the blackdamp needed to be identified to allow AML funding for abatement of the project.

Stable isotopic analysis ($^{13}C/^{12}C$) of the carbon dioxide identified that the gas was inorganic in origin, specifically, from dissolved carbonate material in the spoil. The water chemistry also supports a high capacity to dissolve carbonate material. The overburden analyses of the mine spoil showed a significant source of carbonate material in a glacial till at the site. The normally attractive neutralization potential of this glacial till combined with the waters from the adjacent abandoned mine to produce a detrimental source of CO_2.

BACKGROUND

On August 11, 2000, the Office of Surface Mining's (OSM) Federal Reclamation Program received a complaint from the office of State Representative LaGrotto regarding two of his constituents who reside in Washington Twp., Lawrence County, PA. They were Jason Parker, and Jack and Lisa Burk. These individuals were complaining about high concentrations of carbon dioxide and low oxygen levels in their homes. The symptoms were difficulty in breathing, anxiety, and one family went to the hospital with flu-like symptoms. An initial investigation by OSM on August 16, 2000, produced a third complainant, Larry Geiwitz, with similar problems.

The three properties of this project have similar symptoms, although the Geiwitz's problem seemed most severe. Each of the three properties has different site conditions and backgrounds. The Parker home is over 100 years old, recently remodeled and has a new addition. The older portion of the home had a stone foundation and an earthen basement floor. The gas appliances in the basement often extinguished before or during storms. The poor quality air often filled the basement, coming from the earthen floor and concrete block walls of the addition. High concentrations of CO_2 were measured in exterior pilasters located on the south side of the home. Little or no CO_2 was observed in the two water wells adjacent to the house.

The Geiwitz's home is a large, brick, ranch style home with a full basement about three years old. The basement is finished and their children have bedrooms in the basement. The home has no gas appliances, and is well built and tight. The home is located on a recently reclaimed strip mine. The residents complained of shortness of breath and anxiety often as storms approached. They would watch the barometer to anticipate the problem of low O_2 in their basement. These people worked extensively on their home to control the influx of poor quality atmosphere. First, they added vents to the French drain system around the foundation of the home. Second, they installed an air exchange system that replenished fresh air through the HVAC system. Finally, they installed a sub-slab ventilation system, similar to that used to control radon. Only small amounts of improvement were achieved with each modification. Measurements indicated that the gas was entering the basement through cracks and construction joints in the basement floor.

The Burk's home is a brick ranch home about two years old with a full basement. The basement foundation is partially exposed, with an on-grade, integral garage. The home has no gas appliances. The strip mine came to within 200 feet of the home and the site was used as a spoil stock pile. The residents went to the hospital one time when the air quality was very poor. However, by the time they arrived at the hospital most of their symptoms were gone. The homeowners did nothing to control the low O_2 but open windows when the atmosphere became stale. High concentrations of CO_2 were measured along the back basement wall at the deepest foundation on the north side of the home. High levels of CO_2 were also observed in the shallow hand-dug water well, located about 300 feet southwest of the house.

An Exploratory Investigation was initiated to install three recording gas meters, drill exploratory holes and obtain samples at the three sites. Gas meters have been in place since 11/9/2000 and are down loaded on a routine basis. The drilling was completed on 11/15/2000. Ten holes were drilled, TB-1 through 4 on Parker's property, TB-5 through 7 on Geiwitz's property, and TB-8 through 10 on Burk's property. The drilling investigation was intended to verify if underground mining existed at the site and to identify the source of the low O_2 and high levels of CO_2.

MINING HISTORY

The underground mining in the area was conducted around the turn of the century and abandoned in the 1940's. According to mine maps from the state permit records, the Oakes Mine, operated by Oakes Bros. and Pennsy Mine, operated by Pittsburgh & Erie Coal Company, mined the Brookville Coal Seam. Coal occurs from near the surface to depths of 190 feet.

The mapped underground mines did not extend under the problem sites, and the coal was estimated to be at least 80 feet in depth under the homes founded on bedrock. An abandoned slope entry of the Oakes Mine located about one mile northwest of the Parker site is discharging about 50 gallons per minute of mine drainage with high iron. The mine drainage is collected into a series of ponds then released into a large wetland area.

In 1985, a permit was approved to strip mine coal at the Leesburg No.1 Mine by Willowbrook Mining Co., Division of Adobe Mining Company in the project area. Around 1989 Amerikohl Mining Company took over operation of the bankrupt mine, and recovered the bond money by completing the reclamation of the site.

The large strip mine had pit cuts up to 5200 feet long and an average width of 140 feet with a maximum highwall height of 198 feet. The area of the mine covered over 1800 acres. The overburden was excavated by a Marion 8050 dragline with a 325-foot boom and a 55-cubic-yard bucket, the largest dragline in western Pennsylvania at that time. The four coal seams from deepest to the most shallow that were mined are: Brookville, Clarion, Lower Kittanning, and remnants of the Middle Kittanning.

The initial cut of the mine was about 300 feet southeast of the Parker's residence. The mine plan had an irregular boundary adjacent to the underground mine identified on the northwest edge of the permit. The coal company drilled extensively to avoid the boundaries of the abandoned underground mine but reportedly still uncovered unmapped entries. In 1990 the coal company requested and was approved a variance in the permit allowing disposal of mine tipple waste in mine spoil.

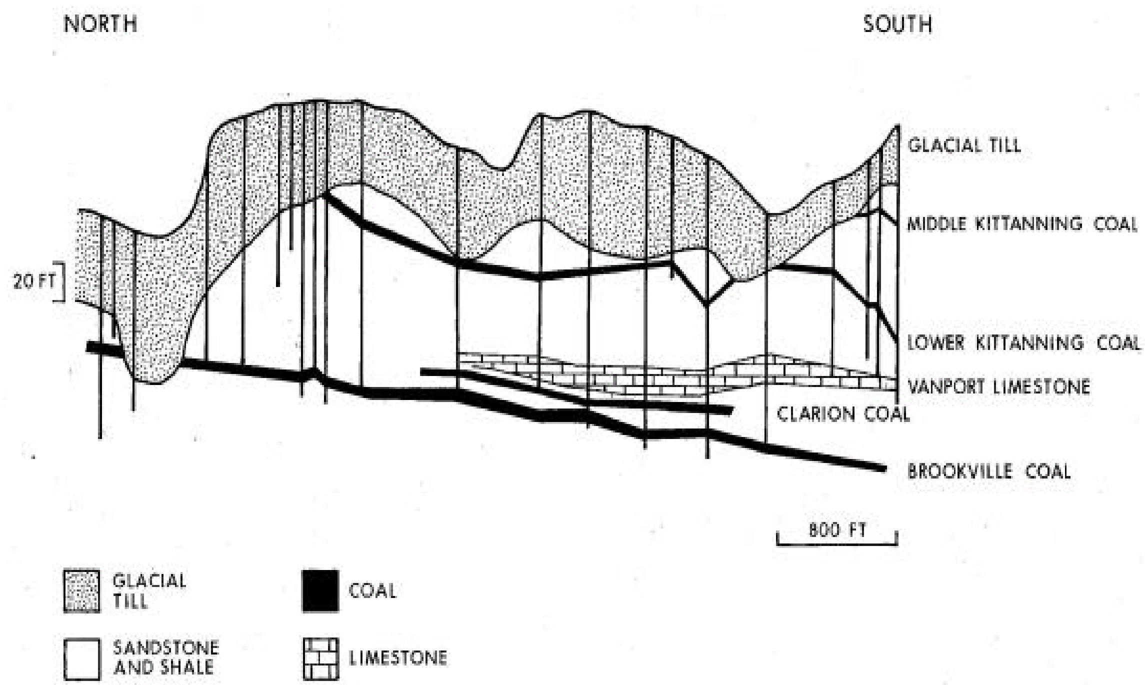

Figure 1 Geologic section across surface mine

The permit allowed the disposal of mine refuse from the company's prep plant. Rumor from local residents was that some land fill waste was also disposed at the site. The mine was designed to use neutralizing materials from the overburden in the backfill to minimize acid mine discharge. The surface mining continued to 1989 after exchanging ownerships. The site was reclaimed and final bond was released in December 2001.

Figure 2 Aerial Photo of Leesburg Mine

During operations, surface mine blasting damaged the Parker's property requiring repairs to the structure and drilling of a new water well. The Geiwitz and Burk homes were not built until mining operations were completed. The site of the Geiwitz home is over a thick section of backfill spoil and the site of the Burk's home is where a backfill stock pile was stripped to bedrock.

GEOLOGIC SETTING

The Parker Project is set in the northern extents of the Appalachian Bituminous Coal Region. The bedrock is composed of sandstone, shale, limestone, and coal of the Kittanning Formation of the Allegheny Group of the Pennsylvanian Period. The thickest coal seam is the Brookville coal averaging about 60-inches thick. The Vanport Limestone is a major marker bed in the region but is not present at the project site. The limestone was eroded away by a facies change or channel cut. The geologic structure of the area is simple. The bedrock dips about 1-2 degrees to the southwest. Most of the local changes in bedding are controlled by depositional patterns.

The surface is covered by a variable thickness of glacial till and outwash. The glacial till is from the Kent Stage of the Pleistocene Period. The glaciations deposited ground till, an end moraine and an outwash channel in the area forming gently rolling topography and an extensive wetland area along an end moraine. The glacial till forms an excellent soil and provides a calcium carbonate for neutralizing materials in mine backfill. Much of the land impacted by the surface mine was characterized as prime farmland, so thick soil overburden was stock piled for reclamation.

Besides coal, gas and oil production have a history in the area. In the 1960's gas and oil exploration produced gas wells from the deeper formations. During mining most of the gas wells were abandoned and the gas wells left have been declining in production. A gas well served the Parker residence but has since been abandoned due to low production. Carbon dioxide is often produced in gas wells as they lose production.

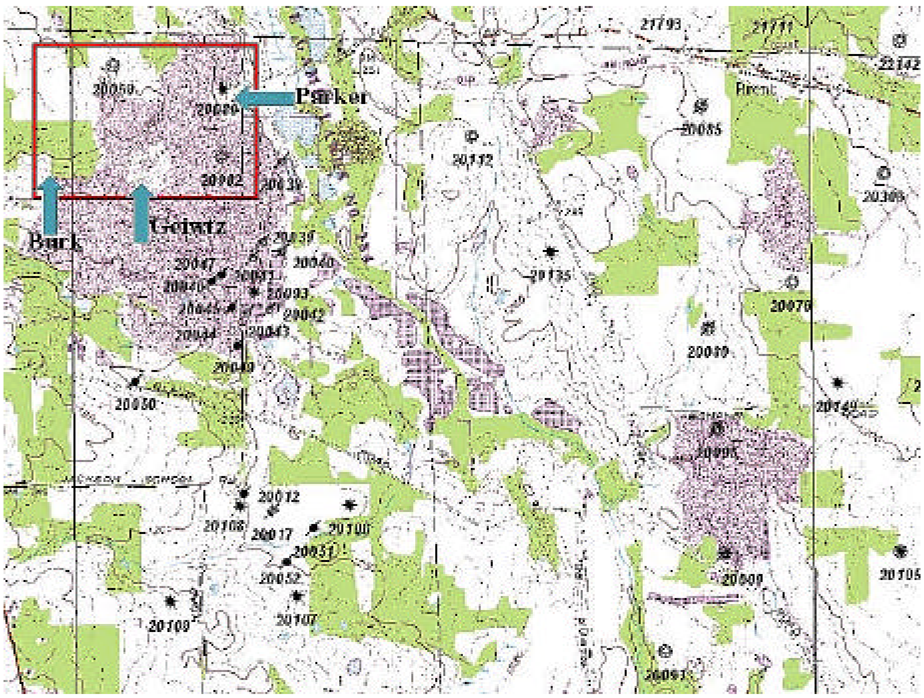

Figure 3 Location of project site and gas wells

Mining has impacted the surface and ground water conditions. The surface water was redirected by the surface mining activities with very little runoff or drainage observed coming from the reclaimed mine. In the unmined areas, a shallow surface aquifer exists in the glacial till. A deeper aquifer is associated with the Brookville coal seam. Fracturing created by mining and old fractures associated with glaciation, connect much of the ground water. This forms a complex system of connected water tables in the bedrock near the mining.

DRILLING DATA SUMMARY

The Brookville Coal is 80-120 feet below the surface, the Lower Clarion is about 40 feet above that seam. None of the drill holes encountered open mine voids. All four holes on the Parker property and two holes on the Burk property were drilled through solid Brookville Coal. One hole on the Burk Property was shallow to sample soil/till, and all three holes on the Geiwitz property went through mine spoil until solid rock was encountered at 120-122 feet depth. Water levels are near the bottom in the spoil holes and variable in the rock holes. The shallowest water level is 21.5 feet in TB-4.

The holes were installed with well screen to sample gases. Gas readings were taken directly after drilling and monthly from 12/2000 to 04/2001. Gas readings in the holes varied with depth and barometric pressure. In general, gas levels increased as barometer dropped and with depth in the hole. The lowest O_2 and highest CO_2 levels were measured in holes TB-2, TB-3, TB-5 and TB-6 directly following drilling: O_2= 3-9% and CO_2 >25%. During a falling barometer gas levels in TB-2, TB-5 and TB-8 were O2 >10% and CO_2 11-21% See Figures 4 and 5 for details on typical holes.

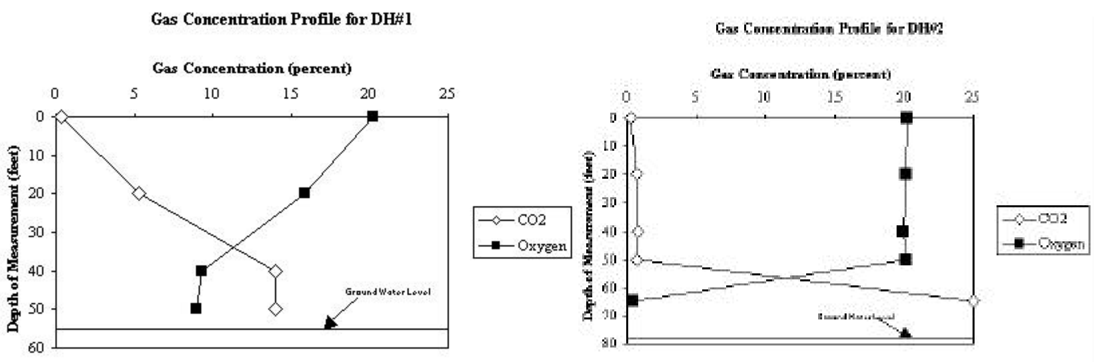

Figure 4 Gas and water levels in bedrock

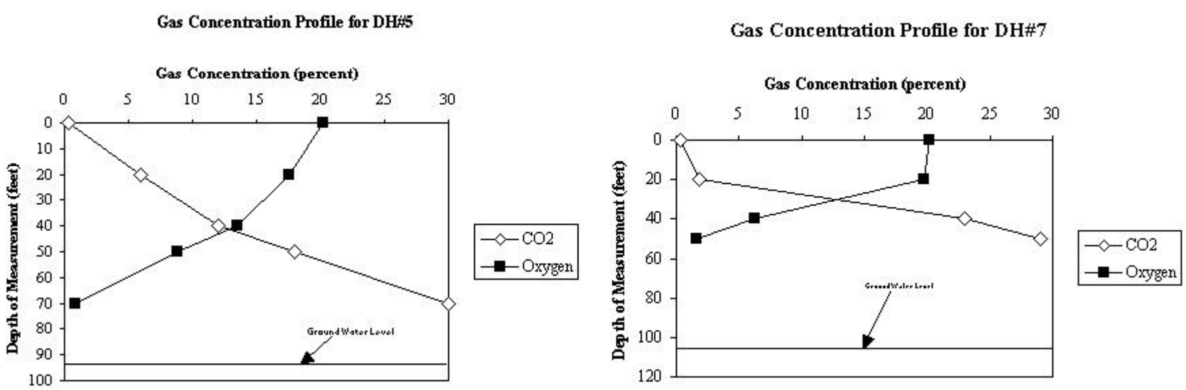

Figure 5 Gas and Water Levels in Spoil

An interesting phenomenon occurred while drilling TB-5 on Geiwitz property through the spoil. Air return was lost, shallow at 30 feet. Near the total depth at 105 feet, rough drilling and voids in the spoil stuck the drill bit. Shortly after air was lost, and a vacuum started in the borehole and continued until the hole was completed. The hole now responds to normal air pressure.   Air was also lost in the other two holes in the mine spoil, TB-6 @100 feet and TB-7 @108 feet. No air loss was encountered in the other holes, drilled through solid rock.

GAS MONITORING SUMMARY

Three Draeger MultiWarn II (MWII) gas monitors were purchased and installed in each of the homes. These monitors measure O_2, CO_2, CO, CH_4 and will record 28 days at 10-minute intervals. Each meter was installed in the basement of each property. The meters were located near the center of the basement, away from drafts but near areas that have shown anomalous gas measurements. The meters were raised on blocks at least six inches above the ground to reduce the layered gas effects. Gas meters were first installed on 11/8/2000 and downloaded monthly.

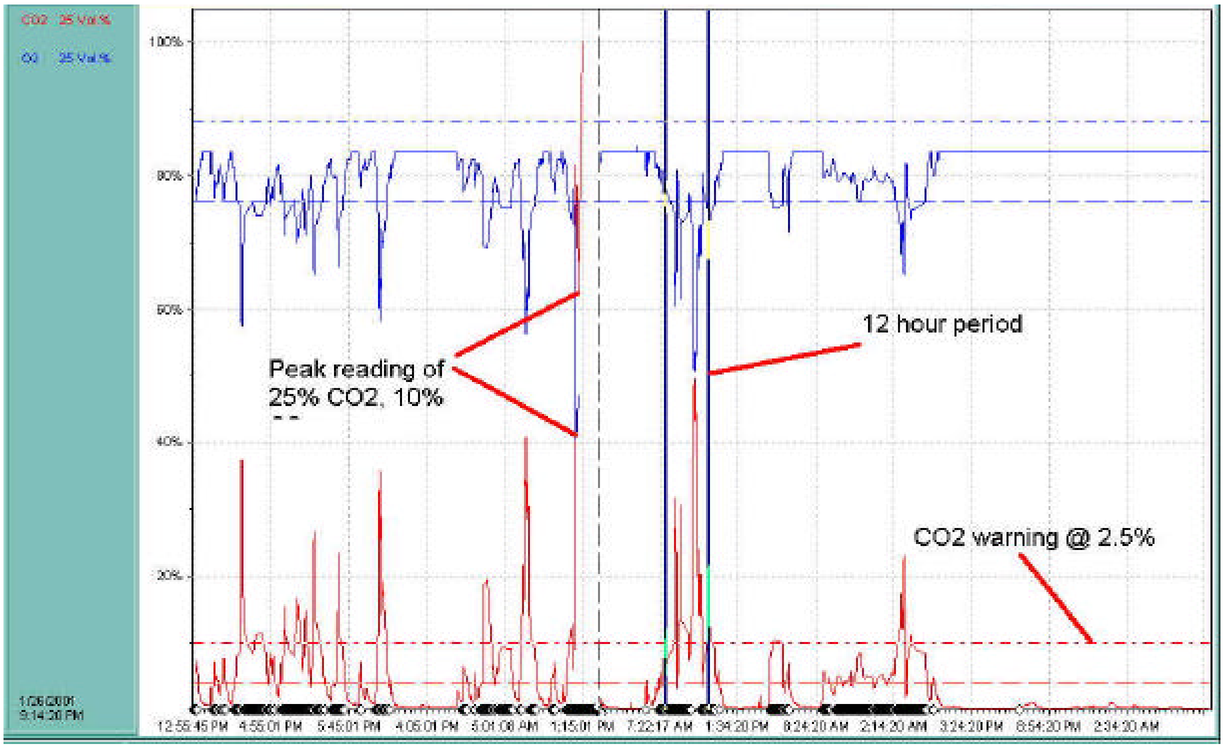

Figure 6 Gas measurements at Geiwitz

The monitor readings at the Geiwitz property showed the worst conditions of the three properties. The gas monitor data showed numerous events when the CO_2 levels were above 2.5% for more than 8 hours. Often the events had peak CO_2 levels above 25.0%. Corresponding oxygen levels peaked to lows of 10% with numerous, extended periods of 8-12 hours below 19.5%. During a rather low barometric pressure of 29.40 measured in Pittsburgh on Sunday morning 12/17/2000, the 12-hour average CO_2 level was 6.3% and the O_2 level was 16.6%. The residents were actively venting the basement during this period. The bad air at the Geiwitz property continued despite efforts by the homeowner to vent and exchange their basement air with fresh air. Since they moved into the property, they have been fighting the problems with the low oxygen and have become very well educated about the problem. They activate fans and open the doors at periods of low barometric pressure or when they feel the high levels of CO_2.

The monitoring of the Burk and Parker properties showed similar, although less severe, results than the Geiwitz property. The poor quality air occurred during periods of low barometric pressure. Some of the events were delayed by a few hours, due to the moving pressure front, or from delays as the gases moved from the source. Long term monitoring showed that the gas problems were worse in the early spring and late fall. These periods historically have more periods of very low barometric pressure, below 29.5 inches of mercury. The changes of the water table and frozen ground surface may also attribute to the gas problem.

HAZARDS

We should digress and discuss the hazards associated with low oxygen atmosphere. Blackdamp is the term commonly used for low oxygen conditions. Its hazard is asphyxiation. Blackdamp is the replacement of normal air, most commonly, with high levels of carbon dioxide and nitrogen. It is the product of adsorption by rock and coal, and microbial action in the mine atmosphere. Carbon Dioxide is also produced by chemical reaction of acidic waters on carbonate rocks and by microbial activity in water and soil. Similarly, oxygen is consumed by oxidation and microbial activity to produce an oxygen deficient atmosphere.

Oxygen meters and carbon dioxide meters commonly measure blackdamp. The gas is denser than air because of the typically large component of carbon dioxide. This gas will also produce an acid taste. Note that carbon dioxide, a principle component of blackdamp, is heavier than air with a Specific Gravity (sp.gr.) of 1.53 and will collect in low spots.

American Conference of Governmental Industrial Hygienists (ACGIH) and U.S. Department of Labor Occupation, Safety and Health Administration have set exposure limits and Threshold Limit Value (TLV's) for the basic components of blackdamp. Oxygen should not drop below 19.5% by volume and carbon dioxide should not exceed the TLV-Long-term-exposure limit of 0.05% by volume. Tables 2 and 3, respectively, show the typical effects of exposure of low levels of oxygen and high levels of carbon dioxide.[1]

Table 1. Physiological Effects of Carbon Dioxide

Carbon Dioxide in Atmosphere (percent)	Increase in Respiration
0.05	Slight.
0.5	Maximum allowable for an 8-hour day.
2.0	50 percent.
3.0	100 percent.
5.0	300 percent and laborious breathing.
10.0	Cannot be endured for more than a few minutes.

Table 2. Effects of Oxygen Deficiency

Oxygen Present	Effect
21%	Breathing easiest
19.5%	Minimum requirement by law
19%	Flame safety lamp gives about one-third the light it gives in normal air (if the atmosphere is methane-free)
17%	Breathing becomes faster and deeper
16.25%	Pilot Lights extinguishes in a methane-free atmosphere
16-13%	Dizziness, buzzing noise, rapid pulse, headache, blurred vision

12.1% . . . . .Flame safety lamp extinguishes
even if methane is present
9% . . . . May faint or become unconscious
6% . . . . Movement convulsive, breathing
stops, shortly after heart stops

SOURCES OF BLACKDAMP

The source of the poor quality air at the Parker project was not apparent from the initial exploratory investigation. The gas monitoring showed changes in air quality as the barometric pressure changed, usually indicative of blackdamp from underground mine sources. Little or no methane was observed in the samples. This implies that the source is not likely from oil and gas wells, or landfills. It's important to determine the source of the gas to determine if a responsible party may aid in the abatement of the problem. If the problem was related to an abandoned mine source, federal or state AML funds can be expended to help abate the problem. However, no underground mines were discovered in the exploratory drilling. Other sources were postulated as possible sources of the very high concentrations of CO_2 as summarized below:

- Underground Mining
- Surface Mining
- Oil and Gas wells
- Septic systems
- Marsh Gas
- Landfill Gas
- Drift Gas
- Subsurface Geology
- Carbonate Dissolution

All of these possible sources could have potentially produced CO_2 at the Parker site. Drilling and gas monitoring identified the problem as more concentrated in the surface mine spoil than the surrounding bedrock. Other investigative tools were required to identify the source of the CO_2. Chemical and isotopic analyses of the blackdamp gas were used to help signature the gas and evaluate the postulated sources.

ISOTOPIC ANALYSIS

Carbon is one of the most abundant elements in nature, and the most important element in the Biosphere. The most common oxidized state of carbon is CO_2. Carbon Dioxide can produce a unique signature based on isotopic analysis of the various carbon isotopes of the gas. Carbon occurs in three common isotopes depending on how and when the carbon compound was formed. The plentiful and stable, natural isotopes of carbon are C^{12} and C^{13}. Normal carbon is 98.89 % C^{12} and 1.11% C^{13}. The isotopes are fractionated by a variety of natural processes, including photosynthesis, combustion and isotopic exchange among carbon compounds. This process tends to enrich C^{12} in biologically synthesized organic compounds. On the other hand isotope exchange reactions between CO_2 gas and aqueous carbonate species enriches carbonates in C^{13}. This can be used to evaluate sources that may be from biogenetic sources, thermogenic sources, such as coal or natural gas, or from carbonate sources.

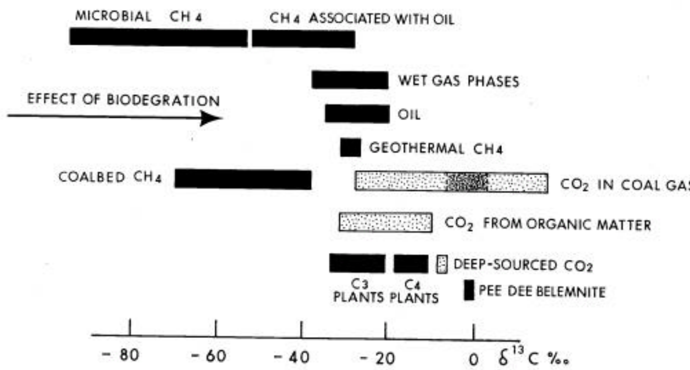

Figure 7 Sources from delta C^{13} Isotopic data

Another isotope of carbon, C^{14} is unstable and produced by interactions of cosmic rays neutrons with nitrogen (N^{14}). This radioactive isotope has a relatively short half-life of 5,715 years, and often is used to date recent organic carbon material like plants and artifacts. The C^{14} isotope has been affected by various natural and industrial activities so it can be used as a marker compared to various sets of standards. For our work, the presence of C^{14} isotope identifies that the source is modern organic carbon found in landfills, septic systems, and other disposed organic material.

The ratio of the change in percent of C^{12} to C^{13} presents distinct signatures for thermogenic gases that do not readily change in time. Isotopic ranges of natural gases such as methane and CO_2 are large in range, specific, predictable, and capable of providing diagnostic information on their source, see Figure 7. Differences in isotopic mass lead to subtle but significant differences in the behavior of an element during natural processes (*fractionation*).

$$\delta\, ^{13}C = \left[\frac{(^{13}C/^{12}C)_{sample} - (^{13}C/^{12}C)_{standard}}{(^{13}C/^{12}C)_{standard}} \right] * 1000 \text{ (permil)}$$

PARKER ISOTOPIC SAMPLES

Samples for isotopic testing were taken from five locations at the Parker project to help identify the source of CO_2. The samples were all taken on January 24, 2001. During this period, the barometric pressure had reached a low of 29.25 in.hg. and began to rise. Two samples from boreholes TB-5 and TB–7 were taken at 25 feet depth in the mine spoil material, with O_2 levels 9% to 8% and CO_2 levels at 15.6% and 17.5% respectively. Two other samples were taken from boreholes in the undisturbed bedrock TB-2 and TB-10 at the Parker and Burk properties, respectively. The fifth sample was gathered from the ambient atmosphere near the floor level of the basement of the Geiwitz's home. This sample had gas concentrations of 13% O_2 and 9% CO_2 in a 6-inch layer above the basement floor. The gas data is presented in Figure 8 below.

Four of the isotopic samples show a similar trend ranging from –2.64 to –7.01 Delta C^{13} per mil. One sample from boring TB-2 had a +2.86 Delta C^{13} per mil. All of the data is close to the PDB standard of zero. The reference standard is CO_2 gas obtained by reacting the belemnites of the Peedee Formation with a 100% solution of phosphoric acid, referred as the PDB standard of the University of Chicago. [2] Note that Figure 7, Plot of various Delta C^{13} Sources, shows that the range around zero is associated with CO_2 gas in coal or from inorganic sources. Organic sources tend to have a less rich or more negative values of Delta C^{13}.

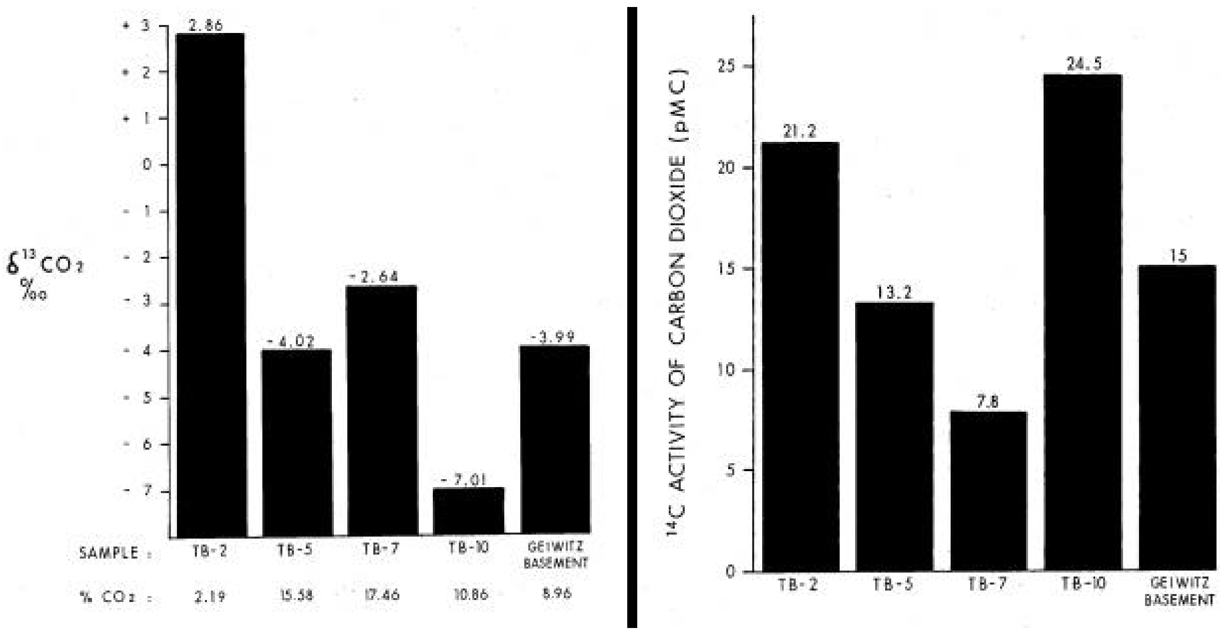

Figure 8 Isotopic data from Samples

Similarly, a thesis drafted by a geology student at Pennsylvania State University investigated the carbon isotope changes in the Vanport Limestone as a precursor for oil and gas exploration.[3] He analyzed many samples of the carbonate and found that Delta C^{13} of the samples averaged –5.0 ¶ ^{13}C. The data again supports that the Delta C^{13} of the samples from the Parker sites is similar. This implies that the CO_2 gas is most likely derived from a carbonate source.

The other isotope of carbon, C^{14} is present in the analysis of samples from the Parker Project, ranging from concentrations of 24.5 to 7.8 parts modern carbon (pMC). The low percentage of C^{14} isotope is not from a modern source such as a landfill or buried organic mater. The slight increase of C^{14} isotope in the samples from the bedrock borings and the ambient atmosphere are related to modern carbon contamination of the samples from water and air.[4] The sample from boring TB-7 most represents the atmosphere in the mine spoil.

CARBONATE SOURCES

The mine records showed that material for neutralization potential was abundant in the glacial till. Neutralization potential (NP) is defined as tons of Calcium Carbonate ($CaCO_3$) equivalent per thousand tons of material. The average neutralization potential of the overburden materials are tabulated below:

Table 3. Overburden Characteristics

Overburden Material	%-Total Sulfur	Neutralization Potential
Glacial till	0.22	54.5
Shale	0.17	17.1
Sandy Shale	0.12	21.7
Sandstone	0.24	13.9
Coal Refuse	3.14	2.45

The overburden material was not high in sulfur, therefore, mine tipple refuse was disposed at the mine in the vicinity of the Parker sites because of the neutralization potential of the overburden, especially the glacial till. The mine plan allowed the disposal of the acidic refuse placed in 2 feet lifts, separated from the high wall and mine floor by clean fill. This would theoretically reduce the production of acid mine drainage from the disposed refuse and place neutralizing material at the base of the mine.

Another source of carbonate material from the Vanport Limestone was not present at the site. The limestone is extensive in the region but was not deposited at the site due to a facies change or may have eroded away in the deposition of channel sands in the formation.

GROUNDWATER ANALYSIS

The theory that carbonate material was being affected from mine drainage, producing CO_2 was introduced by the isotopic analysis. If the theory was correct, ground water analysis should also provide information to support the theory. The ground water seeping from the abandoned underground mines should be highly acidic and low in pH. Water samples were collected from six sites at the Parker Project. Ground water samples and a sample from a drain in the abandoned Oakes Mine showed waters moderately high in alkalinity, ranging from 31.36 to 136.84, and only slightly low pH ranging from 5.82 to 6.55. One normally thinks of the acid-limestone reaction that produces a fizz and CO_2 gas. However, many alkaline waters also have large capacity to dissolve Calcium Carbonate ($CaCO_3$). The water quality data is summarized in the Table 4 below.

Table 4. Water Quality Data

Sample ID	Well #	Date	Time	Depth to water(ft)	pH Field	Sp. Conduct., Field	Temp C
P-1	Mine Drain	8/28/2001	1030	50gpm (flow)	6.31	675	12.2
P-2	TB-4	8/28/2001	1145	46.5	5.97	428	15.5
P-3	TB-7	8/28/2001	1255	106.7	5.82	1900	13.5
P-4	TB-8	8/28/2001	1420	72.7	6.55	120	12

P-5	TB-2	8/28/2001	1545	78.7	6.2	797	12.8
P-6	TB-3	8/28/2001	1615	113.7	6.2	330	14.1
No sample, field check only	TB-9	8/28/2001		43.8	6.48	175	11.8
1	TB-1	9/12/2001		55	6.36		14.1

The more important analysis of the ground water is its capacity to dissolve calcium carbonate as calcite, siderite, and dolomite to create carbon dioxide. This can be calculated as the partial pressure of CO_2 reported as PCO_2. The PCO_2 in the ground water was back calculated to be from 0.01 to 0.2 atmospheres in the ground water. The ground water and mine drain show that they are under saturated in carbonate minerals.

Table 4. Partial Pressure of CO_2 and solubility of Carbonate minerals.

Sample	pH (field)	Alkalinity (mg/L)	pCO2	si_CO2(g)	si_Calcite	si_Dolomit	si_Siderit
Mine Drain	6.31	113.64	0.054450	-1.264	-1.3352	-3.0419	-0.4581
TB-4	5.97	71.6	0.078650	-1.1043	-2.0199	-4.2497	-2.0108
TB-7	5.82	31.36	0.028431	-1.5462	-2.3601	-4.8631	-0.4786
TB_8	6.55	43.98	0.012551	-1.9013	-2.0002	-4.4499	-3.0787
TB-2	6.2	337.1	0.200955	-0.6969	-0.838	-2.0382	-0.1099
TB-3	6.2	136.84	0.088838	-1.0514	-1.4216	-3.2502	-1.4181
TB-1	6.36	110.7	0.048977	-1.31	-1.37	-3.17	0.06

Figure 9 shows the saturation of CO_2 at various pH and Alkalinity values. In general, as the pH drops in value and the Alkalinity rises, then more carbonate can be dissolved and CO_2 exsolved as atmospheric pressure changes.

Carbon Dioxide Concentrations at Varying pH and Alkalinity Values

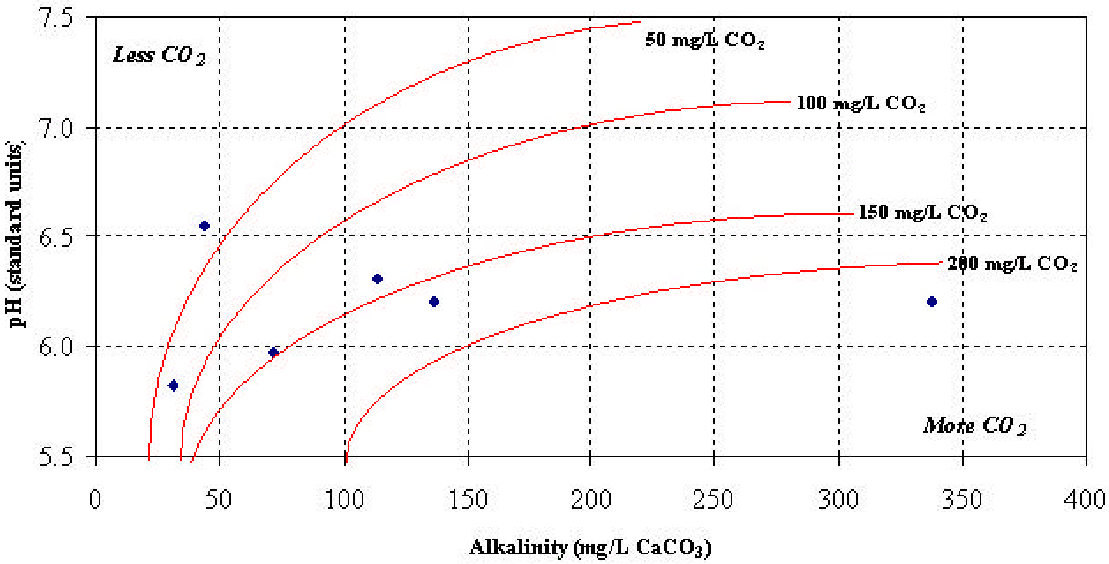

Figure 9 CO_2 and water quality

The on-going mechanism of seepage from the abandoned mine and saturation of the 'neutralizing' materials continues to be a source of CO_2 that is pumped into the deep coarse mine spoil. Mine tipple waste that was disposed in the area added material that would likely lower the pH of the water, further raising the PCO_2 of the ground water. The deep excavation of the surface mine is surrounded by relatively impermeable rock acting as a dam that would create a reservoir for the gas. A change in barometric pressure allows the gas to percolate to the surface first encountering fractures in the adjacent broken ground and eventually filtering into the basements of the homes. In the case of the Geiwitz property, the gas filtrates directly into the basement through the mine spoil and cracks in the foundation. The most likely source of the water for the chemical reaction is the abandoned mine. The recently permitted mine followed standard operating procedures and was no longer responsible. AML funds were approved to abate the problem.

ABATEMENT OF THE PROBLEM

In the case of the Parker Project, the source of CO_2 is large and relatively inexhaustible. Treating the CO_2 at the source would be impossible. Carbon Dioxide is heavier than air and does not easily drain from a structure. Drilling and grouting or installing an earthen barrier wall would not be practical and most likely would have only limited success.

Most current abatement methods act to seal the structure from the gas and provide ventilation to allow the gas to escape. Two of the buildings were recently constructed and appeared to have tight foundations. As mentioned above, the Geiwitz's had experimented with various ventilation techniques to no avail. Their radon system normally evacuated air from the gravel sub-base of the basement floor under negative pressure. In radon systems, the concentration of gas is very small and the supply is relatively slow. The gas can be easily evacuated from the sub-base and exhausted safely outdoors. In the case of our CO_2 problem, the concentration of gas is quite large and the source is near endless. Drawing the gas under negative pressure provides a low-pressure sink to allow more gas to invade the property. The negative pressure often makes the problem worse.

We tried one last technique by modifying the radon system that was installed by the homeowner. This modification is termed a positive pressure radon system. Instead of evacuating the gas from the basement sub-base, fresh air is pumped into the gravel sub-base to displace the CO_2. The fresh air dilutes and creates a fresh air buffer around the property. Figure 10 shows the response of gas readings before and after the fans were reversed at the Geiwitz property. Over a 10-fold decrease in CO_2 levels was observed. Similarly, positive pressure sub-slab ventilation was constructed at the other properties with similar results. Extra work had to be performed at the Parker property to seal an earthen floor and the concrete block.

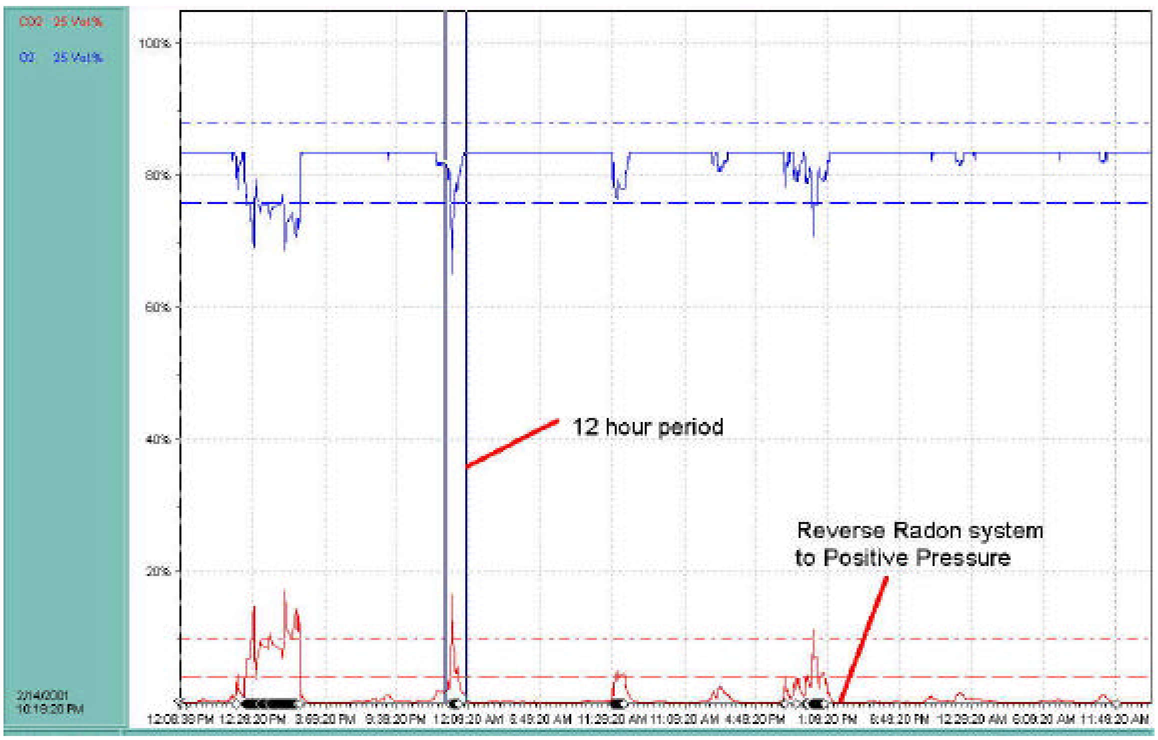

Figure 10. Gas readings after abatement.

SUMMARY

Blackdamp is a low oxygen atmosphere that can be produced by displacement of normal air by carbon dioxide. Blackdamp problems are typically associated with portals and shallow subsidence of abandoned underground mines. The hazard of low oxygen atmosphere is asphyxiation and can result in death. Common symptoms of a low oxygen atmosphere are gas appliances routinely extinguished for no apparent reason.

The source of blackdamp problems associated with surface mines was not clear and thought to be caused by buried organic matter, out-gassing of coal and carboniferous rock, or the interception of open underground mine entries. Data collected from isotopic analysis and supported by ground water analysis indicate that dissolution of carbonate materials can also produce very high CO_2 levels in mine spoil. The isotopic analyses with Delta C^{13} near zero per mil indicate that the CO_2 is from a carbonate source. Groundwater high in alkalinity and with slightly low pH can easily dissolve carbonate material to produce the CO_2.

At least three projects in the northern bituminous coal fields of Pennsylvania and Ohio have had blackdamp problems associated with surface mines. The cause of the problems now appears to be related to ground water reacting with the spoil backfill material. Many surface mines are also designed to augment the backfill with carbonate materials to help reduce acid mine drainage (AMD). A simple by-product of AMD or waters with a high PCO_2 can produce dangerous levels of CO_2. Care in the design of backfill, drains and the post mine use of properties on or near surface mine spoil is required to prevent this type of problem in the future.

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